The current meter works automatically during a fortnight and may be left for that time unattended suspended from one of G. Ekman's submarine buoys.[4] By this mode of suspension, first suggested by the author, one avoids all the errors usually inherent in the ordinary measurements from an anchored ship and due to the proper motion of the latter. The Ekman buoy, by its double anchorage, is kept at a depth of say, 5 or 10 meters below the surface and there stands as firmly as a rock unaffected by the waves and currents of the surface.

A few of these current meters thus anchored in the Strait of Florida or off the coast of Formosa would serve to keep under observation and to record the amount of water carried northward; thus it would be possible to determine the possibility of using such information in making seasonal forecasts of the temperatures over the eastern United States and Europe, or over Japan.

Conclusion.

Notwithstanding the brilliant results gained through individual efforts like the cruises of Sir Frithiof Nansen or of Johan Hjort and Sir John Murray, the vast field of research offered by the ocean calls for international cooperation on a large scale, if the desired harvest of useful results shall be reaped. The following lines for this work appear to the author as particularly worthy of attention:

I. The existing international network of meteorological observations, suspended during the war, should be extended also over the oceans by means of regular observations from an adequate number of transoceanic liners, reporting by wireless. These telegrams also ought to include observations of the temperature and the salinity of the surface water.[5]

II. A special survey of the most important cold and warm currents and their regions of junction or conflict should be systematically maintained by cruisings of research steamers fully equipped for meteorological and hydrographical observations.

III. The internal movements, both horizontal and vertical in the stratified water near the coasts should be followed by regular observations from a sufficient number of fixed stations and lightships along the coast line. The results should be compared with those from simultaneous hydrobiological observations (prevalence of fish eggs, larvæ, and fish food or plankton) and the yield of the local fisheries, both as regards quantity and quality, and also with observations of the local weather, the occurrence of fogs, and, in cold climates, the freezing of fiords and bights.

If the oceanographers and meteorologists of the United States, of Canada, and of Japan were to unite their efforts with those of northwestern Europe in research along these or similar lines we should undoubtedly soon be on the high road to new and startling scientific discoveries and also to results of the greatest practical value.

ON WORKING UP PRECIPITATION OBSERVATIONS.

A number of the younger station officials, enthusiastic in the development and discussion of meteorological data and particularly that relating to the rainfall of the country, have proposed projects of study that seem to indicate a lack of familiarity with the more fully developed methods of analysis of observational data and processes for eliminating defects or errors due to changes in methods or in observers or other things that bring about discontinuity in a long series of observations. *In order to assist such students in the problem of discussing* our rainfall observations, we offer the following translation of selected passages in Dr. Hugo Meyer's "Guide to the working up of meteorological observations for the benefit of climatology."[1] Although the original is over 25 years old, the methods presented are still standard and the principles stated are still regarded as fundamental.—*Chief of Bureau.*

HOMOGENEITY OF THE OBSERVATIONAL MATERIAL.

In working up or discussing meteorological observations the very first care of the student must be to determine the homogeneity of the series of observations he is using, i. e., to make sure that the changes in values (both periodic and nonperiodic) arise solely from changes in weather, and that he has excluded all those sudden or gradual changes which may arise from a change in exposure, or in instruments, or in instrumental constants, or from a change in the observer—changes that at times may be of as great a magnitude as a change in location of the station. Therefore, if one is not perfectly certain that the tabulations he desires to discuss in further detail, actually do present the march of the meteorological elements he should undertake to test the homogeneity of the different factors of the series. * * *

Although it really seems to be a matter of course that one should convince oneself of the homogeneity of a series of observations before undertaking further discussion of them; and although Schouw emphasized the point as early as 1827, yet the full bearing of this circumstance has not been fully appreciated until Hann's recent investigations into this point.[3] Hann has also shown the most convenient way for applying tests of homogeneity.

The method for testing the observational material from a station is based on the experience that radical changes in weather are rarely confined to a limited region, rather they take place with the same sign and with more or less equal intensity over extensive districts. Hence *the differences* [in the case of pressure or temperature] *between simultaneous observations at neighboring points, are much more constant than the observed values themselves.*

Accordingly the testing of the observations at a station involves a comparison of the first with the simultaneous observations at a neighboring standard station whose work is of guaranteed accuracy; or if no such standard station is available then the comparison is to be made with simultaneous observations at not less than two neighboring stations.

The first method for comparing the observational results on a meteorological element at different localities which are not too far apart is *the graphic method.* The means for all the years (or months) under consideration are plotted on coordinate paper, using the same scale for each station and arranging the corresponding values at all stations for the same year in the same vertical line; each pair of points for the same locality are then connected by a straight line. In this way one secures a number of broken lines corresponding to the number of stations brought together for comparison. In each of these lines the rises and falls seem to succeed each other without order. On comparing all the curves it must appear, however, that the succession of rises and falls is the same

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[4] *Pettersson, H.* A recording current meter for deep-sea work. Quart. jour. Royal Metl. Soc., London, 1915.

[5] This suggestion by the author has been included in a proposal for the reorganization of the Swedish Meteorological Service, presented to the Government by the Swedish delegates to the International Council for the Exploration of the Sea.

[1] *Meyer, Hugo.* Anleitung zur Bearbeitung meteorologischer Beobachtungen für die Klimatologie. Berlin, Julius Springer, 1891. viii, [4], 187 p., 21½ cm. (Selections are from pp. 43–45, 51, 52, and pp. 132–140.)

[2] See in this connection *Julius Hann.* Untersuchungen über die Regenverhältnisse von Oesterreich-Ungarn. I. Theil: Die jährliche Periode der Niederschläge. Sitzungsber., Kaiserl. Akad. d. Wissensch., math.-naturw. Kl., Wien, 1879, 80-II, 571–635, particularly p. 573–578.

in all of them, and that the corresponding portions of the different curves are mutually parallel or nearly so. Where there are notable departures from this mutual parallelism, then we have to assume an interruption to the homogeneity of the observations at the station which diverges from the others, and should seek the cause for the divergence. Numerous [European] central meteorological offices employ this method for checking at least the most important meteorological factors in the current monthly reports from all their stations.

This graphic comparison is undoubtedly very reliable, yet it is often advisable to substitute for it *a computational method* and particularly when the series of observations under trial is to be reduced to a longer (i. e., to a normal) period, because then the test for homogeneity can be made to yield at the same time the values needed for the reduction to a normal. * * *

[The omitted portions of the discussion apply particularly to reductions of temperature and pressure observations.]

In the case of precipitation records it is perhaps yet more necessary to reduce the measurements to be compared to the same normal period, for it is well known that the amount of rainfall varies greatly with the time and the locality. At first glance, however, these very reasons appear to make such a reduction very difficult. According to Hann,[3] however, this may be carried out with such certainty that for places having only a short series of observation (i. e., less than 10 years) we may, with the aid of the long series at a neighboring standard station, deduce the normal annual amount and its annual period with greater certainty than it is possible to do from the actual measurements alone. Kämtz early expressed the opinion that the seasonal rainfalls of neighboring stations would show mutual relationships, and Hann has not only confirmed this opinion for the seasonal but also shown a great agreement between the monthly falls of stations not too far apart. To be sure this agreement does not appear between the absolute amounts of the rainfalls; but it is all the more striking between the ratios of the monthly to the annual amounts in the relative amounts of precipitation. The latter are almost the same over considerable areas. Accordingly, if we have only a short series of observations for a station A, while for a neighboring station N we have the mean precipitation, s, for the normal period, an amount we may call s_n, then Hann derives the normal rainfall at A for the same normal period, or s_a, by means of the relation

$$s_a = s_n(A/N),$$

where A and N are the rainfalls at the stations A and N for corresponding years. To determine the normal march in the annual period for the station A we then have to assume that the relative distribution among the months is the same for both stations. Thus s_a is to be multiplied successively by the percentage rainfall of the successive months at the standard station N.

This method of reduction is not admissible, however, when stations are rather far apart and particularly not for stations differing more than but little in altitude. Furthermore, "Stations on divides should not be compared with valley stations, even when the horizontal and vertical intervals are slight. In general, however, monthly means derived in this manner possess much greater reliability than means from direct observations which do not cover more than, say, 10 years. Naturally scientific interest requires that these direct means shall also be published."

[When the observational series at one and the same station has been interrupted by changes in exposure, particularly of the raingage, the changes constitute just so many breaks in the homogeneity of the station's record; it should be the first task of the student to secure from the broken record a series of homogeneous observations at the station for the whole time over which observations extend.]

PRECIPITATION OBSERVATIONS.

* * * The rainfall tables present first of all the *mean amount of precipitation of the individual months*, and almost always from direct observations. But these values are not directly comparable; for the months are of different lengths and, other things being equal, the longer month will have the greater rainfall. In order, therefore, to secure the true annual march of rainfall one must reduce the different sums to months of equal lengths, which can be accomplished by making the rainfall proportional to the length of the month. Quetelet[4] and Kreil[5] give in their tables the precipitation per month-day; that is, they divide the mean monthly sums by 28, 29, 30, and 31, respectively. Renou[6] reduced the months to the normal length of $365.25 \div 12 = 30.44$ days. In the writer's investigation of the distribution of precipitation in Germany[7] the month was treated as having a normal length of 30 days, and that decision will here be adhered to because it is somewhat more convenient even though somewhat less exact than Renou's reduction to 30.44 days. In the writer's procedure the February means are to be multiplied by 1.06 and those of the 31-day months by 0.95 as reduction factors.

In this case also one may hold yet closer to the direct observations by assigning the amounts for January 31 and March 1 to the sum for February, in which case the first four months of the year need no further recomputation. The writer's method is perhaps deserving of adoption in preference to those of Quetelet and Kreil—for the further reason that it is more in harmony with the procedures already proposed for other elements [e. g., temperature means]. This method is, however, far from being a generally accepted one, therefore the investigator should never fail to specify whether or no the monthly means have been reduced. Of course the mean annual total will be the sum of the unreduced monthly means.

It is quite sufficiently accurate to give the amounts to whole millimeters, even in the case of the longest series of observations; because the measurements themselves are not sufficiently accurate to justify the retention of the tenths of a millimeter.[8] However, it is advisable to perform the rounding off only on the computed means.

In comparing the annual rain periods of different localities the process is greatly aided by expressing the individual reduced monthly values as percentages of the total amount (i. e., of the sum of the reduced values). In this case it is proper to take into account the tenths of a millimeter, as has been done in column 2 of the illustrative Table 29, below.

[3] *Hann, Julius.* Untersuchungen über die Regenverhältnisse, etc. II. Theil: Veränderlichkeit der Monats- und Jahresmengen, gleichzeitige Vertheilung der letzteren in der Periode 1849–1878. Nachträge: Fünftägige Mittel des Regenfalles und der Regenwahrscheinlichkeit. Sitzungsber., Kaiserl. Akad. d. Wissensch., math.-naturw. Kl., Wien, 1880, II. Abth., 81: 45–79, particularly p. 57.

[4] *Quetelet, A.* Climat de la Belgique, 5. partie. Ann., Observatoire de Bruxelles, 1852, 9:3.

[5] *Kreil.* Klimatologie von Böhmen. Wien, 1865. p. 43.

[6] *Renou, E.* Étude sur le climat de Paris, 2. partie. Annales, Bur. cent. météorol. de France, Paris, 1885. I, p. 259–277.

[7] Hugo Meyer *In* Aus dem Archiv der Deutschen Seewarte, 1888, 11, No. 6.

[8] *Riggenbach.* Die bei Regenmessungen wünschbare und erreichbare Genauigkeit. Verhandl., Naturforsch. Gesellsch., Basel, 1888, Pt. VIII, p. 579.

The amount of precipitation belongs to those meteorological elements, which possess a fixed lower limit while there is no upper limit. We accordingly may except that in general the arithmetical mean is larger than the most frequently observed value, and that the positive departures, Δ_+, from this mean are rarer and therefore larger than the negative departures, Δ_-. As we have seen elsewhere [German text, p. 31] this expectation has been confirmed by experience, and even for regions where rainless months do not occur.

For this reason it would be of great interest to ascertain the "scheitelwerth." To do this for the monthly means, however, would require a greater number of years of observations than are available. Even the longest series in our possession permit us to secure but an approximate idea of the grouping of the individual values about the arithmetical mean. Since the assymetry of distribution of the individual values is very considerable in the case of rainfall, the general law soon appears after all. Thus, for example, I have arranged the 50 years' rainfall measurements at Geneva, published by Plantamour,[9] in successive 10 mm. groups for the two extreme months of February and October, with the result shown by Table 28.

TABLE 28.—*Frequencies of the groups of stated amounts of rainfall at Geneva (based on Plantamour's compilation of 50 years' records).*

Group.	February.	October.
mm.		
0 to 9	5	...
10 to 19	12	1
20 to 29	10	1
30 to 39	6	5
40 to 49	3	2
50 to 59	5	2
60 to 69	3	4
70 to 79	...	4
80 to 89	5	7
90 to 99	...	5
100 to 109	...	3
110 to 119	...	...
120 to 129	...	1
130 to 139	...	5
140 to 149	1	1
150 to 159	...	2
160 and over	...	7
Means	37 mm.	101 mm.

They show, as was to be expected, that the individual values crowd about a point situated between the arithmetical mean and the lower limit; and that the influence of the lower limit on the arrangement of the individual values is plainly recognizable even in the rainiest month.

Further on we shall see that the conditions are quite similar for the mean amount of precipitation of a rain-day. A day having a rainfall equal to the mean ranks as one of the very wet rain-days (zählt zu den sehr ergiebigen Regentagen), the overwhelming majority of all days with precipitation bring, in our climate, considerably less amounts than might have been inferred from the mean value [mean daily rainfall].

As regards the monthly amounts of rainfall it follows from what has been said, that since it is not practicable to determine accurately the corresponding "scheitelwerth" it is at least desirable to tabulate the numbers of positives, Δ_+, and negative departures, Δ_-, from the means. Infact this would seem to be quite necessary in the case of regions having rainless months if one would avoid a wholly distorted view of the rainfall relations. Supan[10] has proposed to compute the "*probability of total lack of rainfall,*" a suggestion which certainly deserves a consideration it has not yet been granted.

The difference between the mean rainfall of the month with heaviest average fall and that of the month with the smallest average fall gives the *amplitude of the annual periodicity* (for Borkum: October – May = 52 mm.) while the ratio between the two gives the *relative annual range* (for Borkum = 2.3).

As in the case of the other meteorological elements, the *mean departure of the monthly rainfalls* has long been determined by adding the departures from the arithmetical mean, disregarding their sign, and dividing the resulting sum by the number of departures. But since, as we have seen, the number and therefore the sum of the Δ_+ differ considerably from the Δ_- it is preferred to compute the mean positive and the mean negative anomalies separately. In this way we ascertain the upper and the lower limits between which the amount of precipitation fluctuates on the average. The mean rainfall will lie nearer the lower than the upper limit.

The reduction of the monthly rainfall observations to months of normal length will as a rule be performed on the means, and it is only in exceptional cases that previously reduced series will be available for immediate discussion. On this account it is advisable to compute Δ_+ and Δ_- for the unreduced values. A procedure all the more permissible since we do not treat these as final in any case. The reason for this is that in general the amount of the mean departure of a number of individual observations from their mean bears a certain relation to that mean [as the author points out in discussing wind observations]. We secure values which better represent natural conditions if we divide the mean departures by the magnitudes to which they relate, i. e., instead of the mean departures we discuss the quotients from their division by the mean values of the monthly rainfalls which quotients we call *the mean relative departures.* This method seems to be all the more appropriate for precipitation data when the departures are very large in comparison with the value by which they are formed. If now, as we have assumed above, we use the unreduced monthly values in computing the departures then we must be careful to use the unreduced mean monthly rainfalls as the divisors in deriving the relative departures; thus we secure again a result that is independent of the differing lengths of the months. This is the way in which we derived the values entered in columns 5 and 6 of Table 29.

Precipitation tables should be further enriched by incorporating the values of *the absolute extremes.* These bear the same relation to the means as do the mean departures; the extremes on the side of the excess falls are throughout more pronounced (bedeutender) than those on the side of the deficient falls. To be sure, here also the different lengths of the months are of influence; however, it seems this is not important, at least for north German conditions (see the work referred to in footnote 5 above), so we need not take it into consideration. It seems advisable to make no reduction at all rather than to undertake a doubtful one, and all the more since the absolute extremes are of interest, first of all, as direct observations.

The sum of the greatest and the least departure gives the "*absolute*" *range* in rainfall of the year's subdivisions during the given series of years. Here also I do not consider the relation to the mean.

[9] *Plantamour.* Nouvelles études sur le climat de Genève. Mem., Soc. de phys. et d'hist. nat., Genève, 1876, 24: 648.

[10] *Supan,* ——. Petermanns Mittheilungen, 1886, 32, No. 132. Literaturverzeichniss, p. 36.

TABLE 29.—*The manner of presenting the character of the precipitation of a locality; illustrated by the character of the precipitation at Borkum (6° 45′ E., 53° 35′ N.) during 1876–1885.*

Month.	Reduced depth.		Departures.				Extremes.		Extreme range.	Probability of a day with—		Rain-density.	Maximum in 24 hours.
			Number of.		Mean relative.		Maximum.	Minimum.		>0.0 mm.	>1.0 mm.		
	1	2	3	4	5	6	7	8	9	10	11	12	13
	mm.	*Per cent.*	Δ +	Δ −	+	−	*mm.*	*mm.*	*mm.*			*mm.*	*mm.*
January	44	5.8	5	5	0.40	0.40	94	16	78	52	32	2.8	22.1
February	56	7.4	4	6	0.46	0.31	96	25	71	63	42	2.9	21.9
March	49	6.5	5	5	0.42	0.42	112	10	102	52	37	3.2	20.5
April	42	5.5	5	5	0.36	0.36	74	9	65	43	24	3.2	25.4
May	39	5.2	4	6	0.67	0.40	97	6	91	45	28	3.8	16.0
June	51	6.9	4	6	0.63	0.42	128	11	117	47	31	3.7	30.0
July	68	9.0	5	5	0.42	0.42	130	3	127	57	39	3.9	32.2
August	87	11.9	4	6	0.59	0.39	156	30	126	57	40	5.1	31.2
September	79	10.4	4	6	0.39	0.26	172	41	131	57	42	4.6	31.5
October	91	12.1	4	6	0.39	0.26	170	42	128	67	49	4.5	25.6
November	83	11.0	4	6	0.38	0.25	157	38	119	68	51	4.1	22.9
December	63	8.4	4	6	0.40	0.27	95	22	74	64	46	3.3	15.2
Year	764	100	5	5	0.12	0.12	942	589	352	56	38	3.7	32.2

The rainfall of any locality is, however, by no means adequately presented by the mere monthly mean falls. One must also determine the precipitation falling within shorter intervals of time, and compute the frequency with which precipitation occurs.

And here the first question is: How define a *"day with precipitation"*?

[Various definitions have been adopted and proposed; the author decides to adopt as a rain-day "a day on which more than 0.0 mm. of precipitation was measured" and urges Hann's proposal universally to supplement this with a statement of the number of the days on which "at least 1 mm. (0.04 inch) precipitation was measured" (columns 10 and 11 in Table 29)].

On account of the various lengths of the month, *the probability of rain*, i. e., the number of rain-days in the month divided by the total number of days is the preferred form of publication. The good agreement between the values in columns 10 and 11 of Table 29, based on different definitions of a rain-day at Borkum, is by no means a general occurrence.

It is more or less common practice to compute and publish the *mean density of precipitation* or *mean rain intensity*, obtained by dividing the mean amount of precipitation by the mean number of rain-days (>0.0 mm.); but the significance of this factor is often overestimated. It is here expressly pointed out that the rain-intensity is only approximately the amount which is most likely to occur on a rain-day; the latter amount is quite considerably smaller. It is a rule, for all values relating to rainfalls, that the "scheitelwerth" is smaller than the arithmetical mean.

The greatest amount of precipitation during a day is of distinctly greater interest than the rain-density. The maximum fall in one day, accompanied by the year of occurrence, should never be omitted from a table of precipitation. If it is practicable to give more precise information as to the duration of considerable falls, this would be very welcome; because in many respects, e. g., in the problems of Hydrotechnics, it is of prime importance to know the volume of water which falls in intense downpours of shorter duration than 24 hours.

The values here discussed have been collected in Table 29 for the island of Borkum (lat. 53° 35′ N., long. 6° 45′ E.) off the mouth of the Ems. They must be regarded as the necessary elements for describing the periodic changes in the precipitation of a locality. However, it is urgently recommended that, whenever it is in any way possible to do so, the rainfall be treated in yet more detail and that first of all one determine *the frequency with which certain threshold values* (Schwellenwerthe) *are crossed* in the precipitation of a day. Among other advantages, such a computation also brings one to a correct estimation of the rain-intensity. For a long time very little work has been done along this line, but the little we have already is rich in interest. Only in this way may one secure a sharp picture of the rainfall conditions and relationships.

551.515 (759)

TORNADO OF APRIL 5, 1917, AT TAMPA, FLA.

By WALTER J. BENNETT, Meteorologist.

[Dated: Weather Bureau Office, Tampa, Fla. MS. received Apr. 14, 1917.]

At 7 a. m. (90th meridian time) on April 5, 1917, a low-pressure area of considerable intensity was central over Illinois, with its longer axis extending north-northwest to south-southeast. Strong winds had occurred on the coast of northwestern Florida during the night. At Tampa the weather was cloudy and warm, the temperature being about 7 degrees above normal at the 7 a. m. observation. The barometer was falling slowly, and the southwesterly winds were increasing. At 9:50 a. m. small-craft warnings for the Tampa district were issued as follows:

Hoist small-craft warnings. Fresh to strong west and northwest winds, probably thunder squalls.

An order for small-craft warnings was later received from the central office.

The maximum wind at the station was 26 miles per hour from the southwest at 11:05 a. m. and the wind continued above 20 miles per hour until about 1:50 p. m. The first thunder was heard at 12:45 p. m.; rain fell from 1:12 to 1:44 p. m. yielding the amount of 0.46 inch for that interval. The barometer continued to fall slowly until after 1 p. m. and then it suddenly rose about 0.02 inch.

A violent thunder squall, coming from the southwest, struck Seddon Island (*A* of fig. 1) about 1:40 p. m. and passed across Hookers Point (*B* in figure). At Seddon Island the wind velocity was estimated at about 90 miles an hour. An outbuilding and a smokestack were wrecked